Multipurpose Activity Definitions and Interfaces to Support Operational Needs (MADISON)

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Abstract

Multipurpose Activity Definitions and Interfaces to Support Operational Needs (MADISON) is a proposed operator-oriented approach to Battle-Management/Command and Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance/Navigation (BM/C4ISR/N). MADISON responds to several challenges within this broad domain: coordinating independent, in-service systems to support complex operations; interoperability; operator training and operational effectiveness; and, efficient resource allocation. MADISON is neither "platform-centric" nor "network-centric;" it is "operator-centric," intended to position the operator to fight the battle rather than fight the system.

1. Introduction

The United States Navy (USN) inventory contains a variety of independent ("stovepipe") systems in the Battle-Management/Command, Control, Communications, Computing, Intelligence, Surveillance, and Reconnaissance/Navigation (BM/C4ISR/N) domain. This situation carries several disadvantages: the high cost of maintaining separate program offices, hardware, software, documentation, and configuration, maintenance, and training procedures; lack of interoperability; and severe challenges to operators to use the right system at the right time and to switch back and forth among systems effectively.

The USN has heavy investments in shipboard communications systems (such as the Automated Digital Network System[1]), satellite communications (SATCOM) systems (such as the Joint (UHF) MILSATCOM Network Integrated Control System[1]), messaging systems (Defense Message System[2]), data links (such as the Joint Tactical Integrated Data System, Link-16[3]), command and control systems (such as the Global Command and Control System, Maritime, GCCS-M[4]), navigation systems (such as the Navigation Sensor System Interface[5]), and combat direction systems (such as Aegis Command and Decision[6]). Each of these systems, developed at great cost over many years, have attractive capabilities. It is more cost-effective to integrate them

[1] A Space and Naval Warfare Systems Command PMW-176 product
[2] A Space and Naval Warfare Systems Command PMW-166 product
[3] A Space and Naval Warfare Systems Command PMW-159 product
[4] A Space and Naval Warfare Systems Command PMW-157 product
[5] A Space and Naval Warfare Systems Command PMW-156 product
[6] A Naval Sea Systems Command PMS-400 product

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into a single system than to build a new single system. Processes such as "Horizontal Integration" (a SPAWAR Systems Command initiative) and FORCEnet (a Chief of Naval Operations initiative) promise to unify many of these systems. However, unless these initiatives offer an integrated set of operator capabilities and a single-system perspective, they will fall short of the single, integrated BM/C4ISR/N system which the operator needs.

Multipurpose Activity Definitions and Interfaces to Support Operational Needs (MADISON)**,** a proposed operator-oriented approach to BM/C4ISR/N, can offer a single-system perspective. MADISON can provide the operator a mission-related, activity-based interface to the resources he needs to accomplish his mission. Once implemented, MADISON would support complex operations, set clear requirements and metrics for interoperability, unify operator training, improve operator effectiveness, and increase resource allocation efficiency. MADISON is "operator-centric," to position the operator to fight the battle rather than fight the system.

2. **Introduction to MADISON**

MADISON is derived from the activities an operator performs to carry out the mission. An *activity* is a fully or partially-automated operator function (e.g., *engage* target or *send* message). Activities, represented by objects, characterize the types and qualities of service an operator can request. The aggregate of activities represents both operator capabilities and system requirements. The *activity* class is defined in terms of general attributes - including type of service, quality of service, operator role, and activity priority – and methods, including service requests and session control. The activity class includes three subclasses: the *operational* subclass comprises activities which directly support operational requirements; the *management* subclass comprises activities which indirectly support operational requirements by allowing the operator to configure and control resources (e.g., *update* policies, and *distribute* keys); and the *readiness* subclass includes activities which assess resource status and current capability.

Key MADISON design-time system goals are adaptability and testability; operation-time goals include flexibility, interoperability, survivability, and utility. Activities can be used to define and test interoperability, based on activity specifications of data exchanges. MADISON *resource managers* can use dynamic policies (and priority) to resolve resource contention, and use transaction processing to prevent deadlock. The general MADISON technical approach, illustrated in Figure1, incorporates the following concepts.

- Activities are described in common formats and accessed in a common way. An operator accesses activities through an <u>operator interface</u> tailored to him. Each activity is, in general, available to all operators although access restrictions may be imposed by <u>policy managers</u> (shown in Figure 3), based on security, rank, mission, etc. The aggregate of activities represents the (automated) operational capability available to operators.
- Activities obtain service from resources - a resource may be a system, a data distribution network, a database, an input/output device, etc., - via <u>resource interfaces</u>. Operators have (virtual) access to all needed resources and, in general, do not need to know which resources support their activities. The aggregate of possible service requests from activities to resources

comprises requirements for resources. In other words, the formal definition of activities (including functionality, performance, formats, etc.) constitutes a high-level specification for resources to be acquired to implement those activities.

- MADISON resource managers (shown in Figure 3) use dynamic policies (and priority) to resolve resource contention, and use transaction processing to prevent deadlock.

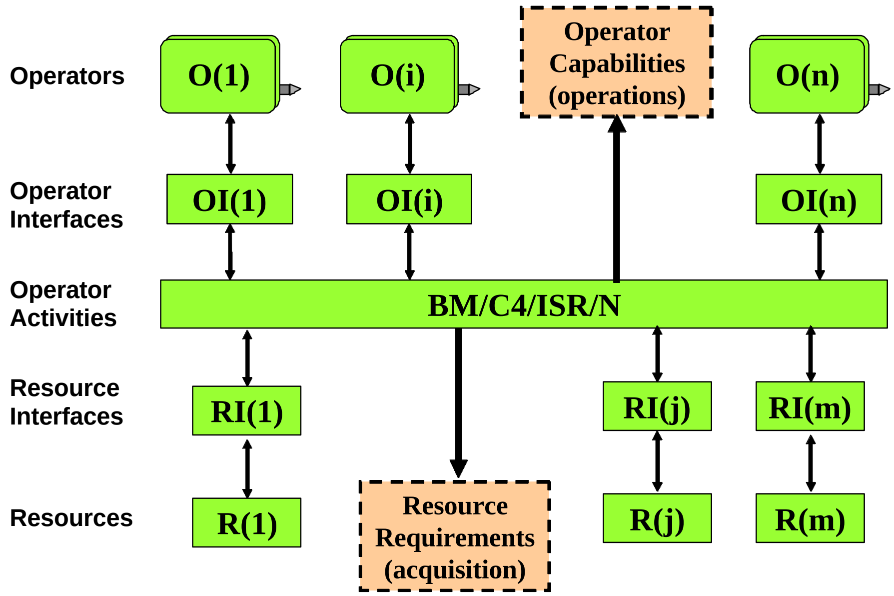

Figure 1. MADISON Architecture

3. Introduction to MADISON.COMMS

MADISON should be developed step-by-step, beginning with a communications segment. This segment, MADISON.COMMS, would comprise communications-based activities to support the operator directly (operator-to-operator communications) and indirectly (operator-to-application and application-to-application communications).

3.1 *MADISON.COMMS Architecture*

Figure 2 shows the MADISON.COMMS Architecture. For simplicity, a single operator (O(i)) is shown. In addition to concepts which apply to the MADISON architecture, note the following.

- O(i) has access to all BM/C4ISR/N activities, separated into (1) COMMS, (2) BM/C2ISR/N, and (3) Computing (not shown - implied to part of all activities). COMMS activities can be requested (directly) by an operator or (indirectly) by BM/C2ISR/N activities ("applications"). The operator does not, in general, see whether or not a BM/C2ISR/N activity is directly supported by COMMS activities.

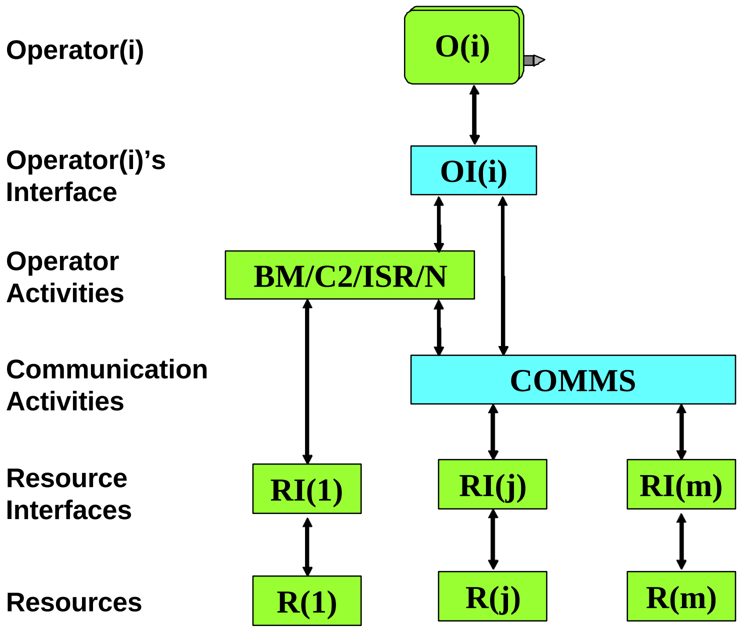

Figure 2. MADISON.COMMS Architecture

3.2 *MADISON.COMMS Activities*

Operational activities for MADISON.COMMS can be derived from Mission Capability Packages (MCPs, now under development in the US Navy[7]) and from current operational capabilities. These are examples of current operational activities: *send*[8], *receive*, *log*, *retrieve*, and *forward* naval message, email, or track report; *establish*, *accept*, and *terminate* voice or data *connection*; *initiate*, *enter*, *exit*, and *terminate* collaborative planning sessions or video teleconferences; *establish* and *disestablish* radio emissions control (EMCON); and *transfer* files, data, and control messages in support of applications. Configuration management activities may include the following: *initialize* and *configure* system or network; and *enter* and *update* policy or user profile. Examples of readiness assessment services include *request* and *accept* resource status report.

These research issues are associated with MADISON.COMMS activity definition: (1) COMMS activities must comprise a complete (covering all direct and indirect communications services required by operators) and internally consistent (minimally redundant and mutually supportive) set (iteration will be needed to address this issue in the absence of a well-defined set of BM/C2ISR/N activities); (2) Qualities of service (i.e., operator-requested service characteristics) must address security and performance constraints and requirements and be implementation-independent; and (3) Operator role and activity priority must be expressed such that they can be used, with defined policies, to make resource-allocation decisions.

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[7] Within the Office of the Chief of Naval Operations, N-7

[8] Send may specify a single addressee, multicast, or broadcast

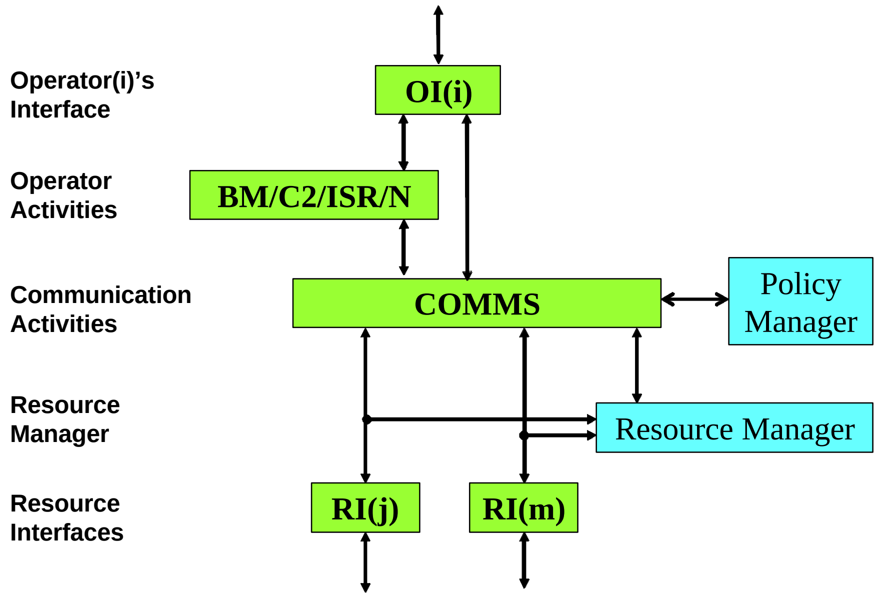

Figure 3. MADISON.COMMS Managers

Figure 3 extends the MADISON.COMMS architecture to include a Policy Manager and a Resource Manager, both critical to MADISON. The Policy Manager determines resource-access rights and activity priority based on operator role, requested or default priority, activity access restrictions, security constraints, operator-access rights, and doctrine. The Policy Manager may be initialized and reconfigured through an activity. The Resource Manager allocates resources to activities based on these criteria: 1) resource suitability, the ability of the resource to deliver the type and quality of service requested by the activity, the comparative resource cost (ideally, the least capable available resource that can meet the request is selected, reserving more capable resources for more demanding jobs); 2) resource availability, the ability of the resource to meet operational constraints (e.g., an EMCON activity may constrain emissions), status (on or off, mode, readiness, in use), and an indication of whether the resource can be pre-empted by a higher priority activity; and 3) activity priority, as requested by the operator and verified by the Policy Manager with respect to the user profile and current policies.

3.3 ***MADISON.COMMS Example Activity***

Establish Connection (EC), one of the activities suggested in Section 3.2, supports voice and data connections (a voice connection is effectively a phone call). Envision an operator at a console wearing a headset with a microphone (very common these days); to initiate his connection, the operator "clicks on" the *EC* activity which offers him a menu screen showing options, each of which can be bypassed in favor of a default (to save time). The first option might be the type of call, e.g., voice message, voice conversation, voice and data (graphics), etc; in the case of a message, the caller might request an acknowledgment (of receipt). A set of options could relate to the receiver(s) of the call. Receivers might be designated by number, name, or role, or from a

directory (directories of receivers and phone numbers (or IP addresses) would be dynamically updated). Another set of options would address the archiving of messages and conversations. Still another would allow rapid retry of previously requested services.

There could be complementary options for the *accept connection (AC)* activity, including modern commercial services such as caller ID, call-waiting indications, automatic or operator-activated call forwarding, and accepting callers into a conversation in-progress. The services which support the *EC* and *AC* activities have been implemented successfully by industry.

4. **A Look at the Supply Side**

If we view MADISON.COMMS activities as the "demand side" of communications operations, it is reasonable to ask whether it is feasible to meet these demands. The Traffic Flow Engineering[9] (TFE) project at SSC San Diego [Otte, 2002] addresses the issue of independent communications systems from the "supply side" and promises to meet many of the requirements imposed by MADISON.COMMS activities. In particular, the TFE project will implement some or all of these features: "(a) *Automated bandwidth management* over all links in the network; (b) *Automated routing* of tactical data over a heterogeneous collection of naval communications systems; (c) *Quality of Service* techniques to ensure guaranteed latency and accuracy of tactical data over limited bandwidth links; (d) *Information assurance* capabilities including authentication, encryption and data integrity at all network layers; (e) *Convergence of data/voice/video* over Internet Protocol [IP] networks; and (f) *Alternatives to legacy IP routing* such as latency-based routing and policy-based routing." [Otte, 2002]

The TFE project defines traffic-flow engineering as "the process of controlling link utilization through advanced <u>policy</u>**,** <u>classification</u>**,** <u>priority</u>**,** and <u>path selection</u> mechanisms." The project goal is to use these mechanisms to "optimize information exchange by controlling the flow of information and the utilization of data links" and then apply the results "to the Naval Battleforce Network[10] (NBN)." [Otte, 2002]

"Policy in this context is the set of rules that govern information flow throughout the network. Policies are used to determine how information exchanges are supported within the network. They tie together a number of traffic-flow engineering components such as classification, prioritization and path selection. Policy management tools permit modification of communications policies in order to keep pace with changing objectives, environments, and priorities. In the NBN, policy management functions may be distributed among centralized network operations center activities as well as those closest to the line of fire." [Otte, 2002] A policy manager is necessary to implement MADISON, as has been described.

"Classification is the process of identifying the packets that make up an information exchange. Classification is a critical component of traffic-flow engineering that permits the special treatment of information exchanges and flows vice packets. Once classified, information flows are provided

[9] Sponsored by the Office of Naval Research (ONR 313)

[10] Part of the Office of Naval Research's Future Naval Capability (FNC) for Knowledge Superiority and Assurance

the prioritization and path-selection capabilities they require." [Otte, 2002] Under MADISON, classification would be inherited from an activity attribute.

"Prioritization is simply the process of identifying and assigning a relative level of importance to information exchanges. Prioritization is also needed to meet the differing requirements of voice, video, data, and mission-critical data." [Otte, 2002] Under MADISON, priority would be inherited as an activity attribute.

"Path selection is the process of identifying and choosing a link or combination of links to a destination. Legacy routing algorithms perform this function. Shortcomings in legacy routing protocols and metrics fail to address mission-oriented path selection requirements. Traffic-flow engineering goes beyond legacy routing by providing path selection based upon mission-centric criteria, such as reliability, latency, security, probability of intercept, and load. It also provides advanced load balancing and load distribution capabilities. Policy Based Routing (PBR) is one example of the advanced path selection techniques available." [Otte, 2002] Path selection would be hidden from MADISON.COMMS activities.

"As an investment strategy, the Navy has migrated many of its communications requirements onto IP-based networks. As a result, the Navy benefits from the substantial research, development, and capabilities of Internet technologies. The need to converge voice, data and video over a common infrastructure is now a popular industry trend. Early voice, video and data convergence efforts are underway but current IP network implementations do not accommodate the different traffic types well. The different requirements of voice, video and data have been a major stumbling block toward successful convergence and effective communications exchange. This condition has prompted significant developments in traffic-flow engineering technologies.

"Historically, the Navy utilized a dedicated link for a specific information exchange requirement. More recent Navy communications architectures promote a de-coupling of individual links and information exchanges. The de-coupling strategy promotes a situation in which multiple links are made available to support multiple information exchange requirements.

"Although it has been a goal of Navy architectures for quite some time, legacy router-based IP networks do not effectively re-assign information flows to links with underutilized or idle capacity. Deficiencies in current implementations of routing protocols, routing metrics and load-balancing algorithms fail to provide this capability. In current networks, some links remain idle while others experience significant congestion. Policy-based routing and advanced algorithms that permit load balancing across unequal links offer substantial improvement.

"A side effect of more recent Navy architectures is that individual information exchange systems no longer have exclusive access to a link. These systems must compete with each other for the pool of available assets. In this environment, the system may perform better as a whole, but the ability to predict the performance of individual information exchanges is lost. It is a challenging situation where the capacity of terrestrial and shipboard networks vastly exceeds that found in the wireless ship-to-ship and ship-to-shore environment. When information is exchanged across the boundaries between those terrestrial and shipboard networks and the wireless ship-to-ship/shore

networks, the transition from high-capacity networks to low-capacity network systems creates a serious bottleneck. Contention issues routinely prevent or significantly delay the exchange of mission-critical data. Information exchange requirements of naval platforms frequently exceed link capacity. The probability of this is highest during crisis situations. A combination of advanced path selection techniques and prioritization will re-establish predictable information exchange performance and optimize communications within the NBN.

"In the NBN, ship-to-ship links provided by airborne platforms are used to augment existing satellite links terminating in Network Operations Centers (NOCs). The new links and resultant paths add much-needed capability but also complicate current routing architectures. In existing Naval networks, link cost (routing metric) is the mechanism used to determine path selection; mission-centric requirements are not taken into account. Policy-based routing and more advanced routing protocols permit mission-centric path selection based upon reliability, latency, and load. Navy IP-based communications systems will benefit from traffic flow engineering technology that improves the flow of information through oversubscribed links and selects optimal paths throughout multiple-link systems.

"The technologies discussed above represent the virtually "off-the-shelf" commodities available for system integration with a high likelihood of success. In many cases the technologies and capabilities discussed above exist in the devices planned for the NBN (e.g., the next-generation ADNS router, Cisco 3600). In addition, the substantial commercial and economic motivation for these technologies ensures their rapid maturity and evolutionary progress." The TFE project is tracking "industry standards and technology development in traffic flow engineering" and monitoring "vendor product developments and participate in the Internet Engineering Task Force (IETF) and related conferences such as the Internet Bandwidth Management Summit (IBAND)." This will provide information as to the current state of the art and give insight into future developments. These are areas of particular interest: "(a) Policy management; (b) Packet classification techniques and the effect of encryption; (c) IP Precedence; (d) Differentiated Services (Diff-Serv); (e) Integrated Services (Int-Serv); (f) Multi-Protocol Label Switching (MPLS); (g) Application-aware networks; (h) Network-aware applications; (i) Policy-Based Routing (PBR); and (j) Secure routing updates based upon MD5 authentication." [Otte, 2002]

The TFE project is developing "a system-wide architecture for the deployment of traffic flow engineering technology within the NBN. The architecture will permit the deployment of policies that promote End-to-End IP Quality of Service (IP QoS) and advanced path selection... Key characteristics of the system include: (a) Adaptable policies; (b) Predictable, reliable and available information exchanges; and (c) Security. Key strategies of the architecture include keeping intelligence at the edges of the network, maintaining scalability, minimizing complexity and utilizing cost effective technologies." [Otte, 2002] A link between the TFE project and the MADISON concept is being explored.

5. **Example Thread**

A thread follows an instantiated activity through the system (in this case, a hypothetical system). A three-way conversation with supporting graphics is chosen for illustration here. The software packages shown in blue in figures 4-9 are part of MADISON. The operator supplies the specifications shown in yellow. His menu selections result in the following description.

Activity: ***Establish Connection:*** voice connection + graphics (data)
Attribute: Caller: Operator a on Platform A O(A(a))
Receivers: Operator b on platform B O(B(b))
Operator c on platform C O(C(c))
Service: Type: Confirm participants (using control messages)
Quality: acknowledgment required
Attribute: Priority (requestor range = 1:30): Requests activity priority 25
Attribute: Session: Start 150800Z SEP 02; End 150900Z SEP 02
Service: Type: Establish voice connection
Quality: One speaker at a time
Service: Type: Establish data connection
Quality: Speaker sends graphics

To begin service, the Policy Manager first must confirm that the requested priority is available to the operator, as shown in Figure 4.

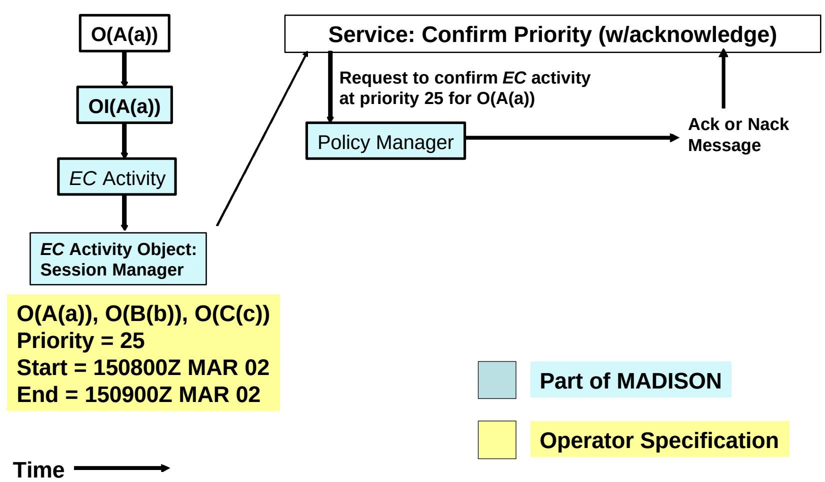

Figure 4. Example Thread – Confirm Priority

Figure 5 shows the Activity Object Session Manager sending a message, over a path selected and designated by the Resource Manager, to confirm participant availability.

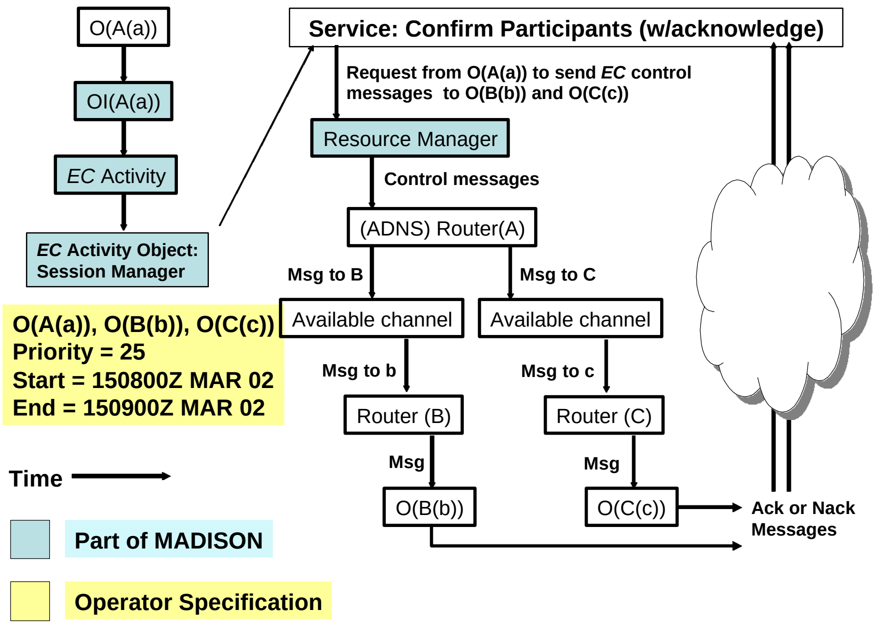

Figure 5. Example Thread – Confirm Participants

In Figure 6, the Resource Manager attempts to establish the required connections to accomplish the requested service.

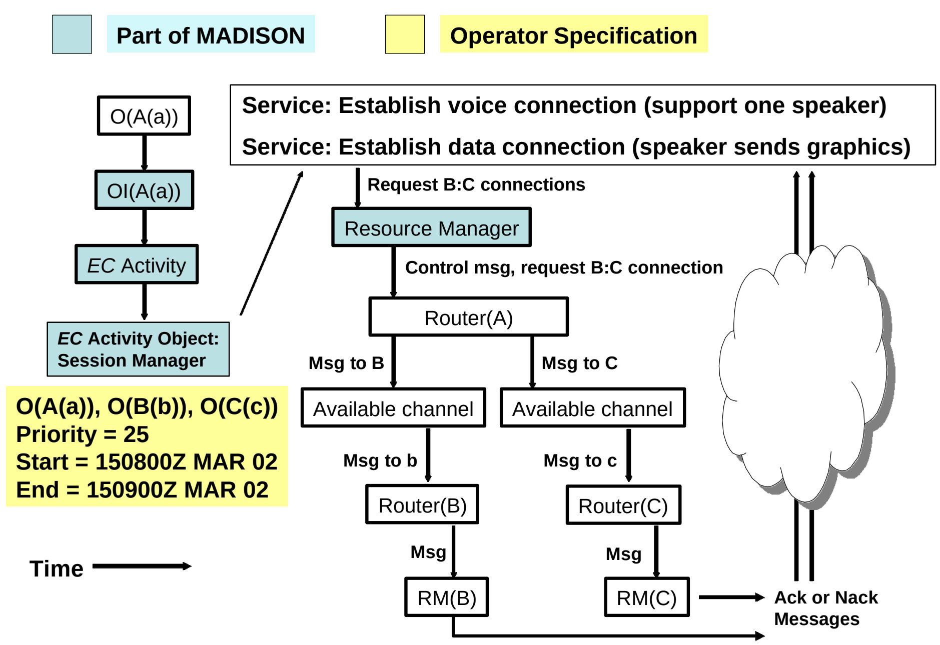

Figure 6: Example Thread – Confirm B:C Connection

The request cannot be satisfied as submitted; the operator is offered four options as shown in Figure 7.

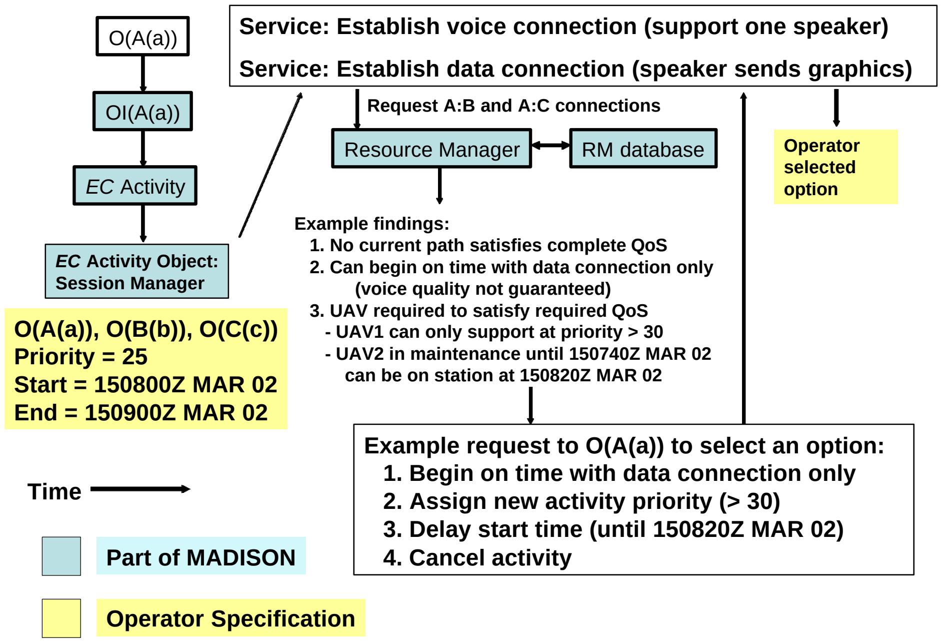

Figure 7: Example Thread – Establish A:B and A:C Connections

Once the session has actually begun, an operator must push the talk button and then see his own talk light come on before he can speak (and be heard by the other operators); this was part of the service request. This service is managed by MADISON as shown in Figure 8.

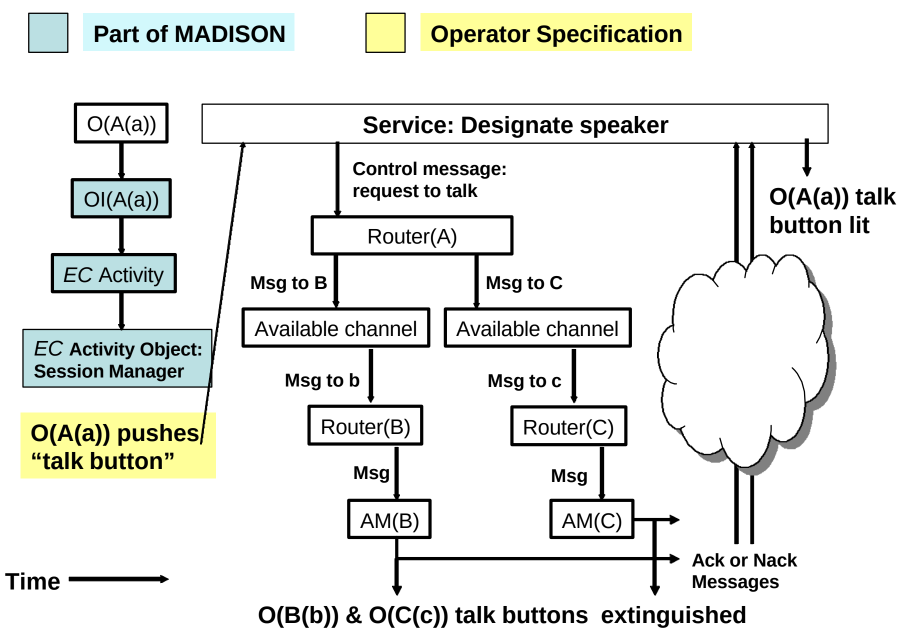

Figure 8: Example Thread – Conduct Session #1

Figure 9 reminds us that an operator whose talk light is lit may send graphics to the others.

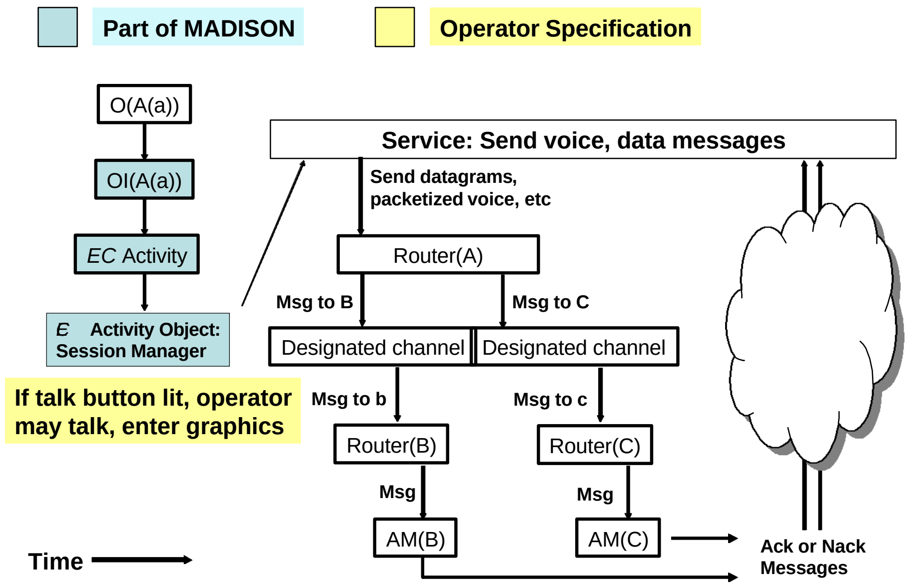

Figure 9: Example Thread – Conduct Session #2

6. Extending MADISON.COMMS Activities

This section indicates how MADISON activities, which extend across the BM/C4ISR/N domain, would be derived; they would then be used to complete the set of MADISON.COMMS activities. The example illustrates how MADISON operator activities, were derived from a given set of missions and capabilities, to support development of C4ISR Concepts for Street-Fighter[11].

6.1 *Selecting MADISON Activities*

Mission areas and capabilities are listed below.

- Mine Warfare: Detection, classification, identification, neutralization
- Anti-Submarine Warfare: Detection, classification, localization & track, neutralization
- Special-Operations Support: Insertion, extraction, mission support, search and rescue
- Reconnaissance, surveillance, and target acquisition : Reconnaissance, surveillance, signals exploitation, target acquisition
- Precision targeting: Land attack, naval surface fire support, air strike support, battle damage assessment
- Surface warfare: Detection, classification/identification, area denial, engagement, battle-damage assessment
- Littoral oceanography: Bathymetry, photogrammetry, hydrography, instrument/sources deployment

[11] A concept from the Naval Warfare Development Command

- Electronic attack: Jamming, spoofing, deception
- Air defense: Search, acquire, track, engage, assess kill/damage

The mission areas and capabilities were first rewritten using operator-action verbs (with objects in parentheses). Note the reuse of verbs.

- Mine Warfare: Detect (mine), classify (mine), identify (mine), engage (mine)
- Anti-Submarine Warfare: Detect (sub), classify (sub), localize (sub), create (sub) track, engage (sub)
- Special-Operations Support: Insert (sof), extract (sof), support (sof), localize (sof), rescue (sof)
- Reconnaissance, surveillance and target acquisition: Deploy surveillance assets, sense, analyze signals, acquire target
- Precision targeting: Engage (Land target [using various options]), assess (battle damage)
- Surface warfare: Detect (surface target), classify (surface target), identify (surface target), define area, engage (surface target), assess (battle damage)
- Littoral oceanography: Analyze (ocean conditions [using various options], deploy (instrument/sources)
- Electronic attack: Jam (radios, sensors), spoof (radios, sensors), deceive (radios, sensors)
- Air defense: Search, acquire, track, engage, assess kill/damage

Based on the above partition, a matrix (not shown) of mission areas and common activities was drawn. Activities that were shared among several mission areas were identified for formal definition; an activity appearing just once was combined with a similar activity (such as create (track) and track) or a companion activity under a single interface (e.g., insert and extract special operations, or jam, spoof, and deceive). Activity renaming followed activity combining: for example, *sense* includes detect and search; *classify* includes identify; *engage* includes acquire; *track* includes create and localize; *support* includes insert, extract, and rescue; *deploy* includes defend area; *analyze* includes assess; and *do EW* includes jam, spoof, and deceive. After a few refinements, the table in Figure 10 resulted to show seven separate (possible) interfaces and eight operator activities, all but one common to more than one mission area.

	Mission	MW	ASW	SOF	PT	SurfW	ElecA	AD
Activity								
Sense		x	x	x	x	x		x
Classify		x	x			x		
Track		x	x	x		x		x
Deploy						x	x	x
Support				x				
Engage		x	x		x	x		x
Analyze		x	x	x	x	x		x
Do EW						x	x	x

Figure 10. User Activities under User Interfaces

6.2 ***Defining Activity Objects***

Once defined in depth, these operator activities embody the capabilities which the operators require to support the given mission areas and it is possible to build the objects that represent them. These objects can be used differently depending upon the mission area. The activity class is defined here first in terms of sets of attributes and methods. The object definition can be formalized under a methodology (e.g., Rational Rose) or in a programming language (e.g., C++).

- Operator-activity attributes
  - Type: *Sense; Classify; Track; Deploy; Support; Engage; Analyze; Do EW*
  - Operator: Name; Role; Authority
  - Operator interface: Screens
  - Time: Initiation; Response
  - Supporting nodes, resources, functions; …
  - Constraints: Time; Distance; Resources
  - Others: Action list; Priority; Status; Alerts; Contention; Rules of Engagement; …

- Operator-activity methods
  - Create activity specification: Include Time, Action list, Priority, Supporting Nodes
  - Verify executability: Check status, alerts, execution issues
  - Show execution issues: Contention, ROE, Proximity to friendly forces, Constraints
  - Initiate activity
  - Allocate resources
  - Manage session
  - Manage alerts
  - Process user output
  - Process external input
  - Close session

The next step is to clarify which attributes and methods apply to which activities and under which mission areas. The somewhat conflicting goals are to faithfully support each mission area and activity while achieving commonalities wherever possible.

7. **Payoffs**

Developing MADISON will yield several payoffs. At requirements time, MADISON activities will provide a <u>missing link</u> between capabilities (such as those expressed under MCPs) and BM/C4ISR/N system implementations (such as those described for the TFE project). Formal definition of BM/C4ISR/N activities will provide the theoretical basis for a single operator interface to the implementing system(s); the aggregate of activities will represent the capability available to an operator; and, the activities will represent BM/C4ISR/N system requirements. These system requirements will motivate and validate efforts such as the TFE project, highlight the items of highest interest, and build on the results of these “supply side” efforts. Formal system requirements, developed and owned by the government, will be visible to all system builders.

At design time, upgrades to the general infrastructure will be integrated and tested with respect to well-defined interfaces and services yielding adaptability. Activity definitions provide formal specifications of what activities (and implementing resources) must accomplish and clarify necessary system services. As they stabilize and are made widely available, activity specifications become visible targets for implementers. Competition to provide implementation improvements could yield long-term cost and performance gains. Activities can only work if system specifications are internally consistent and provide for successful resource allocation and data transfer. Interoperability is necessary to successful activity execution and can be tested, activity by activity; this means that interoperability is well-defined and verifiable. Success in capturing common features across multiple activities will yield software reuse. If pursued on a broad basis, MADISON can provide a framework for integrating systems and operations across the BM/C4ISR/N domain. At test and evaluation time, the activities become both concept demonstration and assessment points and system test and evaluation points.

At training time, operators need only be trained on one system (interface) and therefore the training and rating processes can be simplified. Since activities are mission-related, since commonality will lead to frequent use, and since operators will train on the "real" interface, operators can be expected to become very familiar with their activities. Familiarity should bring about operator efficiency during training (and then during operations). Activities specified with respect to mission, rather than system operation, will make learning the system and learning (to support) the mission complementary. A single interface solves the problem of training operators to use multiple systems and to use the "right system at the right time," thereby assuring improved effectiveness during operations.

At operation time, MADISON supports operators in the performance of their mission, rather than challenges their ability to operate the system. This is a big payoff, like allowing a race-car driver to focus on driving while his sponsor and pit crew worry about tires, engine, fuel, etc, and should provide rapid mission-related response. A tailored interface provides ease of use. On his side of that interface, the tactical operator sees operational activities – formulated as types and qualities of service – and is thus shielded from implementing-system details. At the same time, technical users have access to management and readiness activities to address system issues. Operator-directed activities will call upon implementing resources to distribute only data necessary to operations and will therefore use available bandwidth and computing power efficiently.

8. **References**

[Otte, 2002] Eric Otte, *Traffic-Flow Engineering*, Proposal and Working Papers [unpublished], edited by Jerry McMurry.